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ALGAL GROWTH AQUEOUS FACTORS OTHER THAN NITROGEN AND PHOSPHORUS. SELECTED BIOLOGICAL REFERENCES

Kenneth M. Mackenthun, et al

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

1966

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PREFACE

DIFFICULTIES WITH WATER use associated with nutrient enriched waters have focused considered attention to those factors stimulating growths of algae—especially to such questions as what causes nuisance algal growths, how they can be controlled, and what their relationships are with each other and with the environment in which they live. It is generally conceded that abundant major nutrients in the form of available nitrogen and phosphorus are an important and a necessary component of an environment in which excessive aquatic growths arise. These have been the subject of a publication* which was " . . . compiled for the engineer and the scientist who are faced with predicting limnological changes resulting from nutrient loadings to standing bodies of water, with recognizing critical concentration values for algal development, and with predicting the effects of fertilizers on aquatic life."

Algae, however, are influenced by many and varied factors. Vitamins, trace metals, hormones and auxins, extracellular metabolites, autointoxicants, viruses, and predation and grazing by aquatic animals are factors that stimulate or reduce algal growths. Some of these may be of equal importance to the major nutrients in influencing nuisance algal bloom production. It is the purpose of this bibliographic compilation to present to the engineer and the scientist who are confronted with applied control investigations related to pollutants, some of the literature devoted to population influencing factors in the aquatic environment that are sometimes given too little consideration.

* Mackenthun, Kenneth M. 1965. Nitrogen and Phosphorus in Water. An Annotated Selected Bibliography on Their Biological Effects. U. S. Public Health Service Publication No. 1305. 111 pp.

Several vitamins in small quantities are known to be required as growth factors by certain species of algae. In the fresh water enviroment this requirement is variously considered to be met by the vitamin supply contained in soil runoff, in lake and stream bed sediments, as solutes in the water, and as produced by actinomycetes, certain fungi, many bacteria, several algae, and domestic sewage.

Harder, in 1917, is credited with first connecting growth inhibiting substances with algae. As early as 1931, autoinhibiting substances were recognized (Akehurst, 1931). These papers gave rise to a common belief that a plant can create its self-destruction through the production of growth inhibiting substances that it can not tolerate but which may, in turn, stimulate other growths. Natural waters contain these active agents that are secreted and excreted by fresh-water algae. The toxicity of these agents to other algae and bacteria and to fish varies constantly and is not well-understood in the natural aquatic environment. It has been postulated that algae secrete not just one substance but several, some antibiotic, others stimulating. The amount secreted and the net result of the secretions would be determined by the prevalence of one group of substances over the other. Thus, sequences of algal blooms may be expected to occur under conditions of a nutrient supply far in excess of critical values.

In man's quest to reduce major nutrients enriching waters, such as nitrogen and phosphorus, and thereby restore such waters to a greater water use potential, other algal population-influencing factors will have a role in the ultimate success of the restoration efforts. This role is presently neither clearly defined nor understood. It does seem clear that the constant progression of the geologic clock cannot be substantially altered. Despite man's most ardent dreams, lakes now fertile and abundantly productive of algae will never again attain their crystal-clear, pristine appearance that has been imprinted so well on the minds of long-time local residents. The old swimmin'-hole lingers on in local folklore. Potentially, recently defiled waters can be improved substantially, however, by reducing or removing varying causes for algal productivity. By placing all known algal population influencing factors in their proper perspective and by intensifying investigative efforts directed towards the interrelationships of factors most likely to effect population controls, knowledge and nuisance reducing efforts will be enhanced. Lakes, reservoirs, ponds, flowing streams, estuaries, and bays will be improved, and the using public will be benefited.

GENERAL REFERENCES

1. ERICSON, L. E.
   1953. Further studies on growth factors for *Streptococcus faecalis* and *Leuconostoc citrivorum* in marine algae. Arkiv Kemi., Vol. 6, pp. 503–510.

2. FITZGERALD, G. P.
   1964. The Biotic Relationships within Water Blooms in Algae and Man. (D. F. Jackson, Ed.) Plenum Press, New York, pp. 300–306.

3. FOGG, G. E.
   1953. The metabolism of algae. Methuen and Co., Ltd., London, pp. 1–149.

4. FOGG, G. E.
   1956. The comparative physiology and biochemistry of the bluegreen algae. Bact. Reviews, Vol. 20, pp. 148–165.

5. GOLUEKE, C. G., W. J. OSWALD, and A. B. GOTAAS
   1957. Anaerobic digestion of algae. Applied Microbiol., Vol. 5, pp. 47–55.

6. HARTMAN, R. T.
   1960. Algae and metabolites of natural waters. The Ecology of Algae, Spec. Pub. No. 2, Pymatuning Laboratory of Field Biology, University of Pittsburgh, pp. 38–55 (1959).

7. KRAUSS, R. W.
   1958. Physiology of the fresh-water algae. Ann. Rev. Plant Physiol., Vol. 9, pp. 207–244.

8. KRAUSS, R. W.
   1961. Fundamental Characteristics of algal physiology. Algae and Metropolitan Wastes. U. S. Public Health Service, SEC, TR W61–3, pp. 40–47.

9. LEWIN, J. C. and R. A. LEWIN
   1959. Auxotrophy and heterotrophy in marine littoral diatoms. Inter. Oceanograph. Congress, Preprints. A.A.-A.S., Washington, pp. 928–929.

10. PRESCOTT, G. W.
1960. Biological disturbances resulting from algal populations in standing waters. The Ecology of Algae, Spec. Pub. No. 2, Pymatuning Laboratory of Field Biology, University of Pittsburgh, pp. 22–37 (1959).

11. PROVASOLI, L.
1958. Nutrition and ecology of protozoa and algae. Ann. Rev. Microbiol., Vol. 12, pp. 279-308.

12. RODHE, W.
1948. Environmental requirements of fresh-water plankton algae. Symbolae, Botanicae Upsalienses, Vol. 10, pp. 1–149.

13. RYTHER, J.
1954. The ecology of phytoplankton blooms in Moriches Bay and Great South Bay, L. I., N. Y. Biol. Bull., Vol. 106, pp. 198–209.

14. SEIWELL, H. R.
1931. A consideration of some external factors governing the production of plankton in the sea. J. Ecol., Vol. 19, pp. 164–176.

15. SHILO, M., and M. ASCHNER
1953. Factors governing the toxicity of cultures containing the phytoflagellate *Prymnesium parvum*. J. Gen. Microbiol., Vol. 8, pp. 333–343.

ANTIBIOTICS

1. ALLEN, M. B. and E. Y. DAWSON
1959. Production of antibacterial substances by benthic tropical marine algae. Jour. Bact., Vol. 79, pp. 459–460.

2. BRIAN, P. W.
1957. The ecological significance of antibiotic production. Microbiol. Ecology. Cambridge Univ. Press, pp. 168–188.

3. BURKHOLDER, P. R. and L. ALMODOVAR
1960. Antibiotic activity of some marine algae of Puerto Rico. Bot. Mar., Vol. 2, pp. 149-156.

4. CHESTERS, C. G. C. and J. A. SCOTT
1956. The production of antibiotic substances by seaweeds. Second International Seaweed Symposium (edit. Braarud and Sorensen). Pergamon Press, pp. 49–54.

5. DAVIDSON, F. F.
1961. Antibacterial activity of *Oscillatoria formosa* Bory extract. Water and Sewage Works, Vol. 108, pp. 417–420.

6. FLINT, L. H. and C. F. MORELAND
1946. Antibiosis in the blue-green algae. Amer. J. Bot., Vol. 33, p. 218. (Abst.)

7. FOTER, M. J., C. M. PALMER, and T. E. MALONEY
1952. Antialgal properties of various antibiotics. Antibiotics and Chemotherapy, Vol. III, pp. 505–508.

8. GORBUNOV, K. V.
1963. Development of microbiological processes in water of the Lower Part of the Volga River Delta. Trad. Vsesoyuz. Gidrobiol. Obshch., Vol. 13, p. 94.

9. GREIN, A. and S. P. MEYERS
1958. Growth characteristics and antibiotic production of actinomycetes isolated from littoral sediments and material suspended in sea water. J. Bact., Vol. 76, pp. 457–463.

10. KOKIN, K. A.
1961. Some data on the competitive relationships between the phytoplankton and saprophytic microorganisms in a polluted water body. Nauch. Dokl. Vysshei Shkolye Biol. Nauki., No. 2, p. 132.

11. LEFEVRE, M.
1932. Recherches sur la biologie et la systematique de quelques algues obtenues en cultures. Rev. Algol., Vol. 6, fac. 3–4, pp. 313–338.

12. LEFEVRE, M.
1937. Technique des cultures cloniques de Desmidices. Ann. Sc. Nat., Bot., Ser. 10, p. 19.

13. LEFEVRE, M.
1958. Contribution to the knowledge of bacteria in stagnant water and their role in hydrobiology. Hydrobiologia, Vol. 12, pp. 55–72.

14. LEFEVRE, M. and G. FARRUGIA
1958. The effect on freshwater algae of the products of natural decomposition of organic substances of animal and plant origin. Hydrobiologia, Vol. 10, pp. 49–65.

15. PRATT, R.
1942. Some properties of the growth inhibitor formed by *Chlorella* cells. Am. J. Botany, Vol. 29, pp. 142–148.

16. PRATT, R. et al.
1944. Chlorellin, an antibacterial substance from *Chlorella*. Science, Vol. 99, pp. 351–352.

17. PROCTOR, V. W.
1957. Some controlling factors in the distribution of *Haematococcus pluvalis*. Ecology, Vol. 38, pp. 457–462.

18. PROCTOR, V. M.
1957. Studies of algal antibiosis using *Hematococcus* and *Chlamydomonas*. Limnol. and Oceanog., Vol. 2, pp. 125–139.

19. PROVASOLI, L., I. J. PINTNER, and L. PACKER
1951. Use of antibiotics in obtaining monoalgal bacterial—free cultures. Proc. Am. Soc. Protozool, Vol. 2, p. 6.

20. ROSENFELD, W. D. and C. E. ZO BELL
1947. Antibiotic production by marine microorganisms. J. Bact., Vol. 54, pp. 393–398.

21. SIEBURTH, J. MCN.
1959. Antibacterial activity of antarctic phytoplankton. Limnol. and Oceanog., Vol. 4, pp. 419–423.

22. SIEBURTH, J. MCN.
1960. Acrylic acid and "antibiotic" principle in *Phaeocystis* blooms in antarctic waters. Science, Vol. 132, pp. 676–677.

23. SIEBURTH J. MCN. and P. R. BURKHOLDER
1959. Antibitotic activity of antarctic phytoplankton. Preprints Intern. Oceanog. Cong. A.A.A.S., pp. 933–934.

24. SPOEHR, H. A.
1945. Chlorellin and similar antibiotic substances. Carnegie Inst. Washington Yearbook, Vol. 44, pp. 65–71.

25. SPOEHR, H. A. and H. W. MILNER
1949. The chemical composition of *Chlorella;* effect of environmental conditions. Plant Physiol., Vol. 24, pp. 120–149.

26. SPOEHR, H. A., J. H. C. SMITH, H. H. STRAIN, H. W. MILNER, and G. J. HARDIN
1949. Fatty acid antibacterials from plants. Carnegie Institution of Washington Publication 586, p. 67.

27. STEEMAN NIELSEN, E.
1955. An effect of antibiotics produced by plankton algae. Nature, Lond., Vol. 176, p. 553.

28. STEEMAN NIELSEN, E.
1955. The production of antibiotics by plankton and its effect upon bacterial activities in the sea. Deep-sea Research, 3 Suppl., pp. 281–286.

29. TELITCHENKI, M. M. and V. D. FEDOROV
1962. The interrelation between algae and bacteria in reservoirs. Bull. Soc. Nat. Moscou, Ser. Biol., Vol. 67, p. 148.

30. WILLIAMS, L. G.
1960. Uptake of caesium—137 by cells and detritus of *Euglena* and *Chlorella.* Limnol. and Oceano., Vol. 5, pp. 301–311.

31. ZO BELL, C. E.
1936. Bactericidal action of sea water. Proc. Soc. Exp. Biol. Med., Vol. 34, pp. 113–116.

AUTOINHIBITORS

1. AKEHURST, S. C.
1931. Observations on pond life, with special reference to the possible causation of swarming of phytoplankton. J. Roy. Micros. Soc., Vol. 51, pp. 231–265.

2. HARDER, R.
1917. Ernährungsphysiologische Untersuchungen an Cyanophyceen, hauptsächlich dem endophytischen *Nostoc punctiforme.* Z. Bot., Vol. 9, p. 145.

3. JORGENSEN, E. G.

1956. Growth inhibiting substances formed by algae. Physiol. Plantarum. Vol. 9, pp. 712–726.

4. LEFEVRE, M.

1932. Recherches sur la biologie et la systematique de quelques algues obtenues en cultures. Rev. Algol., Vol. 6, pp. 313–338.

5. LEFEVRE, M.

1937. Technique des cultures cloniques de Desmidices. Ann. Sc. Nat., Bot., Ser. 10, p. 19.

6. LEFEVRE, M., H. JAKOB, M. NISBET

1952. Auto et heteroantagonisme chez les algues d'eau douce in vitro et dans les collections d'eau naturelles. Ann. de la Stat. Centr. d'Hydrob. appl., Vol. 4, pp. 5–198.

7. LEFEVRE, M., M. NISBET, and E. JAKOB

1948. Action des substances excretees en culture, par certaines especes d'algues sur le metabolisme d'autres especes d'algues. Proc. Intern. Assoc. Limnol, Vol. 10, pp. 259–264.

8. MAST, S. O., and D. M. PACE

1938. The effect of substances produced by *Chilomonas paramecium* on the rate of reproduction. Physiol. Zool., Vol. 11, pp. 359–382.

9. MCCOMBIE, A. M.

1953. Factors influencing the growth of phytoplankton. J. Fish. Res. Bd. Canada, Vol. 10, pp. 253–282.

10. RICE, T. R.

1954. Biotic influences affecting population growth of planktonic algae. Fish. Bull. U.S., Vol. 54, pp. 227–245.

11. SWANSON, C. A.

1943. The effect of culture filtrates on respiration in *Chlorella vulgaris*. Am. J. Botany, Vol. 30, pp. 8–11.

ENVIRONMENTAL FACTORS

1. BROWN, W. H.

1911. The plant life of Ellis, Great, Little, and Long Lakes in North Carolina. Contrib. U.S. Nat. Herb., Vol. 13, p. 323.

2. GREGORY, P. H., E. D. HAMILTON, and T. SREERAMULA
1955. Occurrence of the alga *Gloeocapsa* in the air. Nature, Vol. 176, p. 1270.

3. MAQUIRE, B., JR.
1963 The passive dispersal of small aquatic organisms and their colonization of isolated bodies of water. Ecol. Monographs., Vol. 33, pp. 161–185.

4. OSWALD, W. J. and H. B. GOTAAS
1955. Photosynthesis in sewage treatment. Proc. Amer. Soc. Civil Engr., Vol. 81, Separate No. 686, pp. 1–27.

5. OVEREEM, M. A., VAN
1936. A sampling apparatus for aeroplankton Proc. Roy. Acad., Amsterdam, Vol. 33, pp. 981–990.

6. OVEREEM, M. A., VAN
1937. On green organisms occurring in the lower troposphere. Rec. Trav. Botan. Neerl., Vol. 34, pp. 389–439.

7. PADY, S. M. and C. D. KELLY
1953. Studies on microorganisms in Arctic air during 1949 and 1950. Can J. Botany, Vol. 31, pp. 107–122.

8. PEARSALL, W. H.
1918. On the classification of aquatic plant communities. J. of Ecol. Vol. 6, p. 75.

9. PEARSALL, W. H.
1920. The aquatic vegetation of the English Lakes. J. Ecol., Vol. 8, p. 163.

10. PEARSALL, W. H.
1921. The development of vegetation in the English Lakes, considered in relation to the general evolution of Glacial Lakes and Rock Basins. Proc. Roy. Soc. B., Vol. 92, p. 259.

11. PEARSALL, W. H.
1929. Dynamic factors affecting aquatic vegetation. Proc. Internat. Cong. Plant Sci., Vol. 1, p. 667.

12. PEARSALL, W. H. and A. M. HANBY
1925. The variation of leaf form in *Potamogeton perfoliatus*. New Phytol., Vol. 24, p. 112.

13. PEARSALL, W. H. and T. HEWITT
1933. Light penetration into fresh water. II. Light penetration and changes in vegetation limits in Windermere. J. Exper. Biol., Vol. 10, p. 306.

14. PEARSALL, W. H. and P. ULLYOTT
1934. Light penetration into fresh water. III. Seasonal variations in the light conditions in Windermere in relation to vegetation. J. Exper. Biol., Vol. 11, p. 89.

15. POND, R. N.
1903. The biological relation of aquatic plants to the substratum. Report of the U.S. Commissioner of Fish and Fisheries, Vol. 116, pp. 483–526.

16. PROCTOR, V. W.
1959. Dispersal of freshwater algae by migratory water birds. Science, Vol. 130, pp. 623–624.

17. SAWYER, C. N.
1954. Factors involved in disposal of sewage effluents to lakes. Sewage and Industrial Wastes, Vol. 26, pp. 317–325.

18. SCHLICHTING, H. E., JR.
1961. Viable species of algae and protozoa in the atmosphere. Lloydia, Vol. 24, pp. 81–88.

19. SCHLICHTING, H. E., JR.
1964. Meteorological conditions affecting the dispersal of airborne algae and protozoa. Lloydia, Vol. 27, pp. 64–78.

20. STEVENSON, R. E. and A. COLLIER
1962. Preliminary observations on the occurrence of airborne marine phytoplankton. Lloydia, Vol. 25, pp. 89–93.

21. VEATCH, J. C.
1931. Classification of water soils is proposed. Quart. Bull. Mich. Agr. Exper., Vol. 14, p. 1.

22. VEATCH, J. C.
1933. Some relationships between water plants and water soils in Michigan. Papers Mich. Acad. Sci., Vol. 17, p. 409.

23. WILSON, L. R.
1935. Lake development and plant succession in Vilas County, Wisconsin. Part I. The medium hard water lakes. Ecol. Mono., Vol. 5, p. 207.

24. WILSON, L. R.

1937. A quantitative and ecological study of the larger aquatic plants of Sweeney Lake, Oneida County, Wisconsin. Bull. Torr. Bot. Club, Vol. 64, p. 199.

25. WILSON, L. R.

1939. Rooted aquatic plants and their relation to the limnology of freshwater lakes. A.A.A.S. Pub. No. 10, pp. 107–122.

EXTRACELLULAR PRODUCTS

1. ALLEN, M. B.

1956. Excretion of organic compounds by *Chlamydomonas*. Arch. Mikrobiol., Vol. 24, pp. 163–168.

2. ARMSTRONG, F. A. J. and G. T. BOALCH

1960. Volatile organic matter in algal culture media and sea water. Nature, London, Vol. 185, pp. 761–762.

3. BISHOP, C. T., G. A. ADAMS, and E. O. HUGHES

1954. A polysaccharide from the blue-green alga, *Anabaena cylindrica*. Canad. J. Chem., Vol. 32, pp. 999–1004.

4. CHAMPIGNY, M. L.

1958. Amino acids of *Chlorella* grown in presence of potassium nitrate or urea. Qualitas Plant et Materiae Vegetabiles, Vols. 3–4 pp. 99–100. Chem. Abs., Vol. 53, No. 6, 5414i, March 25, 1959.

5. ERICSON, L. E. and B. CARLSON

1953. Studies on the occurrence of amino acids, niacin and pantothenic acid in marine algae. Arkiv Kemi., Vol. 6, pp. 511–522.

6. FOGG, G. E.

1942. Studies on nitrogen fixation by blue-green algae. I. Nitrogen fixation by *Anabaena cylindrica* Lemm. J. Exp. Biol., Vol. 19, pp. 78–87.

7. FOGG, G. E.

1952. The production of extracellular nitrogenous substances by blue-green algae. Proc. Roy. Soc. B., Vol. 139, pp. 372–397.

8. FOGG, G. E.

1958. Extracellular products of phytoplankton and estimation of primary production. Rapp. Cons. Explor. Mer., Vol. 144, pp. 56–60.

9. FOGG, G. E. and G. T. BOALCH

1958. Extracellular products in pure cultures of a brown algae. Nature, Vol. 181, pp. 789–790.

10. FOGG, G. E. and C. NALEWAJKO

1962. Glycollic acid as an extracellular product of phytoplankton. Verh, Int. Ver. Limnol., Vol. 15, p. 806.

11. FOGG, G. E. and D. F. WESTLAKE

1955. The importance of extracellular products of algae in freshwater. Proc. Inter. Assoc. Theor. and Appl. Limnol., Vol. 12, pp. 219–232.

12. GUILLARD, R. R. L. and P. J. WANGERSKY

1958. The production of extracellular carbohydrates by some marine flagellates. Limnol. Oceanog., Vol. 3, pp. 449–454.

13. HELLEBUST, J. A.

1965. Excretion of some organic compounds by marine phytoplankton. Limnol. Oceanog., Vol. 10, pp. 192–206.

14. HENRIKSON, E.

1961. Nitrogen fixation by a bacterial free, symbiotic *Nostoc* strain isolated from *Collema*. Physiol. Plantarum, Vol. 4, pp. 542–545.

15. HENRIKSON, E.

1957. The physiology of the lichen *Collema*. I. Production of extracellular nitrogenous substances by the algal partner under various conditions. Physiol. Plantarum, Vol. 10, pp. 943–948. Chem. Abs., Vol. 52, No. 22, 20412d, Nov. 25, 1958.

16. JOHANNES, R. E.

1964. Phosphorus excretion and body size in marine animals: Microzooplankton and nutrient regeneration. Science, Vol. 146, pp. 923–924.

17. JOHANNES, R. E.

1964. Uptake and release of dissolved organic phosphorus by representatives of a Coastal Marine Ecosystem. Limnol. and Oceanog. Vol. 9, pp. 224–234.

18. KROGH, A., E. LANGE, and W. SMITH
1930. On the organic matter given off by algae. Biochem. J., Vol. 24, pp. 1666–1671.

19. LEFEVRE, M.
1964. Extracellular products of algae. In Algae and Man (D. F. Jackson, Ed.) Plenum Press, New York, pp. 337–367.

20. LEWIN, R. A.
1956. Extracellular polysaccharides of green algae. Canad. J. Microbiol., Vol. 2, pp. 665–672.

21. MARSHALL, S. M. and A. P. ORR
1955. On the biology of *Calanus finnmarchieus*. VIII. Food uptake, assimilation and excretion in adult and stage V *Calanus*. J. Mar. Biol. Assoc., Vol. 34, pp. 495–529.

22. MERZ, R. C., R. G. ZEHNPFENNIG, and J. R. KLIMA
1962. Chromatographic assay of extracellular products of algal metabolism. Journ. Water Pollution Control Federation, Vol. 34, pp. 103–115.

23. NALEWAJKO, C.
1966. Photosynthesis and excretion in various planktonic algae. Limnol. Oceanog., Vol. 11, pp. 1–10.

24. POMEROY, L. R., H. M. MATHEWS, and H. S. MIN
1963. Excretion of phosphate and soluble organic phosphorus compounds of zooplankton. Limnol. and Oceanog., Vol. 8, p. 55.

25. TOLBERT, N. E. and L. P. ZILL
1956. Excretion of glycollic acid by algae during photosynthesis. J. Biol. Chem., Vol. 222, pp. 895–906.

26. TOLBERT, N. E. and L. P. ZILL
1957. Excretion of glycollic acid by *Chlorella* during photosynthesis, pp. 228–231. In: H. Gaffron (ed.), Research in photosynthesis. Interscience, New York.

27. TSUDA, KYOSUKE et al.
1957. Discovery of cholesterol in some red algae. Science, Vol. 126, pp. 927–928. Chem. Abs., Vol. 52, 3042c, February 25, 1958.

28. TSUDA, KYOSUKE et al.
1958. Steroids. VIII. Cholesterol in some red algae. Chem. Pharm. Bull. (Tokyo), Vol. 6, 101–104. Chem. Abs., Vol. 53, 7324f, April 25, 1959.

29. VOGEL, H. J.
1959. Lysine biosynthesis in *Chlorella* and *Euglena*: phylogenetic significance. Biochim. et Biophys., Acta 34, pp. 282–283.

30. WATANABE, ATSUSHI
1951. Production in cultural solution of some amino acids by the atmospheric nitrogen fixing blue-green algae. Arch. Biochem. Biophys., Vol. 34, pp. 50–55.

31. WHITTINGHAM, C. P. and G.G. PRITCHARD
1963. The production of glycollate during photosynthesis in *Chlorella*. Proc. Roy. Soc. (London), Ser. B, Vol. 157, pp. 366–380.

HORMONES AND AUXINS

1. BACH, M. K. and J. FELLIG
1958. Auxins and their effect on the growth of unicellular algae. Nature, Vol. 182, pp. 1359–1360.

2. BENTLEY, J. A.
1958. Role of plant hormones in algal metabolism and ecology. Nature, Vol. 181, pp. 1499–1502.

3. BENTLEY, J. A.
1960. Plant hormones in marine phytoplankton, zooplankton and sea water. J. Mar. Biol. Assoc., Vol. 39, pp. 433–447.

4. BRANNON, M. A.
1937. Algae and growth-substances. Science, Vol. 86, pp. 353–354.

5. BRANNON, M. A. and A. F. BARTSCH
1939. Influence of growth substances on growth and cell division in green algae. Amer. Journ. Botany, Vol. 26, pp. 271–279.

6. CONRAD, H., P. SALTMAN, and R. EPPLEY
1959. Effects of auxin and gibberellic acid on growth of *Ulothrix*. Nature, Lond., Vol. 184, pp. 554–557.

7. PRATT, R.
1938. The influence of auxins on the growth of *Chlorella vulgaris*. Amer. Jour. Bot., Vol. 25, pp. 498–501.

8. PROVASOLI, L.
1957. Effect of plant hormones on sea weeds. Biol. Bull., Vol. 113, p. 321, (Oct.) (Abstr.). J. conseil. Conseil permanent intern exploration mer., Vol. 24, p. 401, March 1959.

9. PROVASOLI, L.
1958. Effect of plant hormones on *Ulva*. Biol. Bull., Vol. 114, pp. 375–384.

10. PROVASOLI, L.
1959. Growth factors in unicellular marine algae. In perspectives in marine biology, ed. by A. A. Buzzati-Traverso. Berkeley, Univ. Calif. Press, pp. 385–403.

11. SALTMAN, P. D., and H. CONRAD
1962. Response of algae to the gibberellins and other plant hormones. Phycol. Soc. Amer., News Bull., (abstract), Vol. 15, p. 8.

12. THIMANN, K. V. and K. BETH
1959. Action of auxins on *Acetabularia* and the effect of enucleation. Nature, Lond., Vol. 183, pp. 946–948.

13. YIN, H. C.
1937. Effect of auxin on *Chlorella vulgaris*. Proc. Nat. Acad. Sci., Vol. 23, pp. 174–176.

INHIBITING METABOLITES

1. BECKWITH, T. D.
1933. Metabolic studies upon certain Chlorellas and allied forms. Univ. of Calif., Los Angeles Bio Sci., Vol. 1, pp. 1–34.

2. ESPING, U.
1957. A factor inhibiting fertilization of sea urchin eggs from extracts of the alga *Fucus vesiculosus*. I. The prepara-

tion of the factor inhibiting fertilization. Arkiv Kemi, Vol. 11, pp. 107–115. Phycol. Soc. Am., News Bull., Vol. 12, p. 12, April 1959.

3. ESPING, U.

1957. A factor inhibiting fertilization of sea urchin eggs from extracts of the alga *Fucus vesiculosus*. II. The effect of the factor inhibiting fertilization on some enzymes. Arkiv Kemi, Vol. 11, pp. 117–127. Phycol. Soc. Am., News Bull., Vol. 12, p. 12, April 1959.

4. FITZGERALD, G. P.

1961. Stripping effluents of nutrients by biological means. Algae and Metropolitan Wastes. Trans. 1960 Seminar, R. A. Taft S.E.C., US P.H.S. Tech. Report W61–3., pp. 136–139.

5. HARDY, A. C.

1936. Plankton ecology and the hypothesis of animal exclusion. Proc. Linn. Soc. Lond., Vol. 148, pp. 64–70.

6. HASLER, A. D. and E. JONES

1949. Demonstration of the antagonistic action of large aquatic plants on algae and rotifers. Ecology, Vol. 30, pp. 359–364.

7. LOOSANOFF, V. L., J. E. HANKS, and A. F. GANAROS

1957. Control of certain forms of zooplankton in mass algal cultures. Science, Vol. 125, pp. 1092–1093.

8. LUCAS, C. E.

1947. The ecological effects of external metabolites. Biol. Rev. Cambr. Phil. Soc., Vol. 22, pp. 270–295.

9. LUCAS, C. E.

1955. External metabolites in the sea. Papers in marine Biology and Oceanography Suppl. to Vol. 3 of Deep Sea Research, pp. 139–148.

10. LUCAS, C. E.

1958. External metabolites and productivity. Rapp. Cons. Explor. Mer., Vol. 144, pp. 155–158.

11. OPHEL, I. L.

1950. Some ecological effects of substances produced by the Characeae. Proc. Okla. Acad. Sci., Vol. 29, pp. 15–17.

12. PRATT, R.
1942. Studies on *Chlorella vulgaris*. V. Some properties of the growth inhibitor formed by *Chlorella* cells. Amer. J. Bot., Vol. 29, pp. 142–148.

13. PRATT, R.
1943. Retardation of phytosynthesis by a growth-inhibiting substance from *Chlorella vulgaris*. Am. J. Botany, Vol. 30, pp. 32–33.

14. PRATT, R.
1943. Studies on *Chlorella vulgaris*. VI. Retardation of photosynthesis by a growth-inhibiting substance from *Chlorella vulgaris*. Amer. J. Bot., Vol. 30, pp. 32–33.

15. PRATT, R.
1944. Influence on the growth of *Chlorella* of continuous removal of chlorellin from the solution. Am. J. Botany, Vol. 31, pp. 418–421.

16. PRATT, R.
1945. Influence of the age of the culture on the accumulation of chlorellin. Am. J. Botany, Vol. 32, pp. 405–408.

17. PRATT, R.
1948. Studies on *Chlorella vulgaris*. XI. Relation between surface tension and accumulation of chlorellin. Amer. J. Bot., Vol. 35, p. 634.

18. PRATT, R. and J. FONG
1940. Further evidence that *Chlorella* cells form a growth-inhibiting substance. Am. J. Botany, Vol. 27, pp. 431–436.

19. PRATT, R., J. F. ONETO, and J. PRATT
1945. Studies on *Chlorella vulgaris*. X. Influence on the age of the culture on the accumulation of chlorellin. Amer. J. Bot., Vol. 32, pp. 405–408.

20. PRINGSHEIM, E. G.
1935. Ueber Azetatflagellaten. Naturwiss, Vol. 23, pp. 110–114.

21. PRINGSHEIM, E. G.
1954. Ueber Zuckerflagellaten. Naturwiss, Vol. 41, pp. 1–3.

22. PRINGSHEIM, E. G.
1958. Ueber mixotrophie bei flagellation Planta. Vol. 52, pp. 405–430.

23. PRINGSHEIM, E. G.
1959. Heterotrophie bei Algen und Flagellaten. in Handb Pflanzenphysiol. -Springer Vol. 9, pp. 303–326.

24. PRINGSHEIM, E. G. and O. PRINGSHEIM
1959. Die Ernahrung Koloniebildender Volvocales. Biol. Zentralbl. Vol. 78, pp. 937–971.

PREDATION AND GRAZING

1. ALIKUNHI, K. H., K. K. SUKUMARON, and S. PARAMESWARAN
1963. Induced spawning of the Chinese carps, *Ctenopharngodon idellus*, (C. & V.) and *Hypophthalmichthys molitrix* (C. & V.) in ponds at Cuttack, India. Current Science, Vol. 32, pp. 103–106.

2. ALLSOPP, W. H. L.
1960. The manatee: Ecology, and use for weed control. Nature. London, Vol. 188, pp. 752–762 (Fisheries Lab., Dep. Agric., P. O. Box 174, Georgetown, Br. Guiana).

3. ANDERSON, J. M.
1950. Vegetation changes following fish removal. Jour. Wildlife Mgt., Vol. 14, pp. 206–209.

4. AVAULT, J. W., JR.
1965. Preliminary studies with grass carp for aquatic weed control. Progressive Fish Culturist, Vol. 27, pp. 207–209.

5. BAINBRIDGE, R.
1953. Studies on the interrelationship of zooplankton and phytoplankton. J. Mar. Biol. Assoc., Vol. 32, pp. 385–445.

6. BLACK, J. D.
1946. Nature's own weed killer, the German carp. Wisconsin Conservation Bulletin, Vol. 11, pp. 3–7.

7. BROOKS, J. L. and S. I. DODSON
1965. Predation, body size, and composition of plankton. Science, Vol. 150, p. 28.

8. CAHN, A. R.

1929. The effect of carp on a small lake: Carp as dominant. Ecology, Vol. 10, pp. 271–274.

9. CAIRD, J. E.

1945. Algae growth greatly reduced after stocking pond with fish. Water Works Eng., Vol. 98, p. 240.

10. FLEMING, R. H.

1939. The control of phytoplankton populations by grazing. J. Conseil Exploration de la mer, Vol. 14, pp. 1–20.

11. GIBOR, A.

1957. Conversion of phytoplankton to zooplankton. Nature. Vol. 179, p. 1304.

12. GRIZZELL, R. A. and W. W. NEELY

1962. Biological controls for waterweeds. Trans. Twenty-seventh North American Wildlife and Natural Resources Conference, pp. 107–113.

13. HARVEY, H. W.

1934. Annual variation of plankton vegetation. J. Mar. Biol. Assoc., Vol. 19, pp. 775–792.

14. LEAR, D. W., JR., and C. H. OPPENHEIMER, JR.

1962. Consumption of microorganisms by the coperpod *Tigriopus Californicus*. Limnol. and Oceanog. VII (suppl.), pp. 63–65.

15. PENNINGTON, W.

1941. Control of the numbers of fresh water phytoplankton by small invertebrate animals. J. Ecology, Vol. 29, pp. 204–211.

16. PENTELOW, F. T. K. and B. STOTT

1965. Grass carp for weed control. Progressive Fish-culturist, Vol. 27, p. 210.

17. RYTHER, J. H.

1954. Inhibitory effects of phytoplankton upon the feeding of *Daphnia magna* with reference to growth, reproduction and survival. Ecology, Vol. 35, pp. 522–533.

18. SAUNDER[illegible], G. W.

1957. Interrelations of dissolved organic matter and phytoplankton. Botan. Rev., Vol. 23, pp. 389–409.

19. STEVENSON, J. H.
1965. Observations on grass carp in Arkansas. Progressive Fish-culturist, Vol. 27, pp. 203–206.

20. SWINGLE, H. S.
1957. Control of pond weeds by use of herbivorous fishes. Proceedings 10th Annual Meeting, Southern Weed Conference, Augusta, pp. 11–17.

21. THREINEN, C. W. and W. T. HELM
1954. Experiments and observations designed to show carp destruction of aquatic vegetation. Jour. of Wildlife Management, Vol. 18, pp. 247–250.

22. TRYON, C. A., JR.
1954. The effect of carp enclosures on growth of submerged aquatic vegetation in Pymatuning Lake, Pennsylvania. Jour. Wildlife Management, Vol. 18, pp. 251–254.

23. WRIGHT, J. C.
1958. The limnology of Canyon Ferry Reservoir. I. Phytoplankton-zooplankton relationships in the euphotic zone during September and October, 1956. Limmol. and Oceanog., Vol. 3, pp. 150–159.

24. WRIGHT, J. C.
1965. The population dynamics and production of *Daphnia* in Canyon Ferry Reservoir, Montana. Limnol. and Oceanog., Vol. 10, pp. 583–590.

TRACE METALS AND COMPOUNDS

General References

1. ALBERT, LA V., and F. DAVIDSON
1959. The effects of gibberellic acid on *Microcystis aeruginosa*. Texas J. Sci., Vol. 11, pp. 358–365.

2. ARNON, D. I.
1958. The role of micronutrients in plant nutrition with special reference to photosynthesis and nitrogen assimilation. Chapt. I In: Lamb, Bentley, and Beattie, (eds.). Trace elements. Academic Press, Inc., New York.

3. BAKER, D. and J. M. NELSON
1943. Tyrosinase and plant respiration. J. Gen. Physiol., Vol. 26, pp. 269–276.

4. BRENCHLEY, W. E.
1927. Inorganic plant poisons and stimulants. 2nd ed. Cambridge Univ. Press, London.

5. BURDETT, R. M. and L. P. TURNBULL
1960. The effect of gibberellic acid on the growth of *Chlamydomonas moewusii* Gerl. Brit. Phycol. Bull. (Abstract), Vol. 2, p. 13.

6. DAVIS, C. C.
1964. A preliminary report on the effects of indoleacetic acid and gibberellic acid upon the growth of planktonic algae under semi-field conditions. Verh. Internat. Verein. Limnol., Vol. XV, pp. 811–816.

7. DOLEVO-DOBROVOLSKIA, L. B., A. E. GLOOSKOVA, T. N. KOOZIANINA, L. E. ELPNER and V. K. JAKOVLEER
1960. Effect of biomicillin and penicillin on physiological activity of certain aquatic plants. (From a translation of the Russian and a condensation of the paper presented at a Sectional Meeting of Hydrobiology and Ecthology, MDEP, 21 December.)

8. EMERSON, R. and C. M. LEWIS
1942. The photosynthetic efficiency of phycocyanin in *Chroococcus* and the problem of carotenoid participation in photosynthesis. J. Gen. Physiol., Vol. 25, p. 579.

9. EYSTER, C.
1958. The microelement nutrition of *Nostoc muscorum*. The Ohio J. Sci., Vol. 58, pp. 25–33.

10. EYSTER, C.
1964. Micronutrient requirements for green plants, especially algae. Algae and Man (D. F. Jackson, Ed.), Plenum Press, New York, p. 86.

11. EYSTER, H. C., T. E. BROWN and H. A. TANNER
1958. Mineral requirements for *Chlorella pyrenoidosa* under autotrophic and heterotrophic conditions. Chapt. 11. pp. 157–174. In: Lamb, Bentley, Beattie (eds.). Trace elements. Academic Press, Inc., New York.

12. GALLOWAY, R. A. and R. W. KRAUSS
1959. The differential action of chemical agents, especially Polymyxin B, on certain algae, bacteria, and fungi. Am. Jour. Bot., Vol. 46, pp. 40–49.

13. GALLOWAY, R. A. and R. W. KRAUSS
1959. Mechanism of action of Polymyxin B on *Chlorella* and *Scenedesmus*. Plant Physiol., Vol. 34, pp. 380–389.

14. GARNER, W. W.
1935. Chemical elements essential for nutrition of plants. U.S. Dept. Agr. Bur. Plant Indus. Rept., p. 25.

15. GERLOFF, G. C., G. P. FITZGERALD, and E. SKOOG
1952. The mineral nutrition of *Microcystis aeruginosa*. Am. J. Botany, Vol. 39, p. 26.

16. GILBERT, F. A.
1957. Mineral nutrition and the balance of life. University of Oklahoma Press, Norman, Oklahoma.

17. HAMILTON, L.
1953. Utilization of purines for nucleic acid synthesis in chrysomonads and other organisms. Ann. N. Y. Acad. Sci., Vol. 56, pp. 961–968.

18. HATTORI, A.
1958. Metabolism of urea and other nitrogenous compounds in *Chlorella ellipsoidea*. II. Changes in levels of amino and amides during the assimilation of ammonia and urea by nitrogen-starved cells. J. Biochem. (Tokyo, Vol. 45, pp. 57–64. Chem. Abs., Vol. 52, 7435d, May 10, 1958.

19. HEWITT, E. J.
1951. The role of the mineral elements in plant nutrition. Ann. Rev. Plant Physiol., Vol. 2, pp. 25–52.

20. MCELORY, W. D. and A. NASON
1954. Mechanism of action of micronutrient elements in enzyme systems. Ann Rev. Plant Physiol., Vol. 5, pp. 1–30.

21. MCMURTREY, J. E., JR.
1938. Distinctive plant symptoms caused by deficiency of any one of the chemical elements essential for normal development. Bot. Rev., Vol. 4, pp. 183–203.

22. MULDER, E. G.
1950. Mineral nutrition of plants. Ann. Rev. Plant Physiol., Vol. 1, pp. 1–24.

23. MYERS, J.
1951. Physiology of the algae. Ann. Rev. Microbiol., Vol. 5, pp. 157–180.

24. NOACK, K., A. PIRSON, and G. STEGMANN
1940. The need of *Chlorella* for traces of elements. Naturwiss. Vol. 28, pp. 172–173.

25. ONDRATSCHEK, K.
1941. Mineral requirements of heterotrophic flagellates. Arch. Mikrobiol., Vol. 12, pp. 241–253.

26. PIRSON, A.
1955. Functional aspects in mineral nutrition of green plants. Ann. Rev. Plant Physiol., Vol. 6, pp. 71–114.

27. PRITCHARD, G. G., W. J. GRIFFIN, and C. P. WHITTINGHAM
1962. The effect of carbon dioxide concentration, light intensity and isonicotinyl hydrazide on the photosynthetic production of glycollic acid by *Chlorella*. J. Exptl. Bot., Vol. 13, pp. 176–184.

28. REISNER, G. S. and J. F. THOMPSON
1956. The large scale laboratory culture of *Chlorella* under conditions of micronutrient element deficiency. Plant Physiol., Vol. 31, pp. 181–185.

29. STEGMANN, G.
1940. The significance of the trace elements for *Chlorella*. Z. Botanik, Vol. 35, pp. 385–422.

Boron

1. BERGER, K. C.
1949. Boron in soils and crops. Advances in Agron., Vol. 1, pp. 321–351.

2. DENNIS, R. W. G.
1937. Relation of boron to plant growth. Science Progress, Vol. 32, pp. 58–69.

3. EYSTER, C.
1952. Necessity of boron for *Nostoc muscorum*. Nature, Vol. 170 p. 755.

4. GEIGEL, A. R.
1935. Effect of boron on the growth of certain green plants. J. Agr. Univ., Puerto Rico, Vol. 19, pp. 5–28.

5. GREENHILL, A. W .
1938. Boron deficiency in horticultural crops: Recent developments. Sci. Hort., Vol. 6, pp. 191–198.

6. JOHNSTON, E. S.
1928. Boron: its importance in plant growth. J. Chem. Educ., Vol. 5, pp. 1235–1242.

7. JORDAN, J. V. and G. R. ANDERSON
1950. Effect of boron on nitrogen fixation by *Azotobacter*. Soil Sci., Vol. 69, pp. 311–319.

8. MACVICAR, R. and R. H. BURRIS
1948. Relation of boron to certain plant oxidases. Arch. Biochem., Vol. 17, pp. 31–39.

9. MCILRATH, W. J. and J. SKOK
1957. Influence of boron on the growth of *Chlorella*. Plant Physiol., Vol. 32, suppl., p. 23.

10. MCILRATH, W. J. and J. SKOK
1958. Boron requirement of *Chlorella vulgaris*. Botan Gaz., Vol. 119, pp. 231–233. Chem. Abs., Vol. 52, 20454e, November 25, 1958.

11. ROSENBERG, A. J.
1946. Action of boron and of m-inositol on *Clostridium saccharobutyricum*. Compt. rend., Vol. 222, pp. 1310–1311.

12. SHIVE, J. M.
1945. Boron in plant life—a brief historical survey. Soil Sci., Vol. 60, pp. 41–51.

13. SKOK, J.
1958. The role of boron in the plant cells. Chapt. 15. In: Lamb, Bentley, and Beattie (eds). Trace elements. Academic Press, Inc., New York.

14. WARINGTON, K.
1923. The effect of boric acid and borax on the broad bean and certain other plants. Ann. Botany, Vol. 37, pp. 630–670.

Calcium

1. KEVERN, N. R.
1964. Strontium and calcium uptake by the green alga, *Oocystis eremosphaeria*. Science, Vol. 145, pp. 1445–1446.

2. TRELEASE, S. F. and M. E. SELSAM
1939. Influence of calcium and magnesium on the growth of *Chlorella*. Am. J. Botany, Vol. 26, pp. 339–341.

Chlorine

1. ARNON, D. I. and F. R. WHATLEY
1949. Is chloride a coenzyme of photosynthesis? Science, Vol. 110, pp. 554–556.

2. BROYER, T. C., et al.
1954. Chlorine—a micronutrient element for higher plants. Plant Physiol., Vol. 29, pp. 526–532.

3. EYSTER, C.
1958. Chloride effect on the growth of *Chlorella pyrenoidosa*. Nature, Vol. 181, pp. 1141–1142.

4. JOHNSON, C. M., et al.
1957. Comparative chlorine requirements of different plant species. Plant and Soil, Vol. 8, pp. 337–353.

5. MARTIN, G. and J. LAVOLLAY
1958. Chlorine, an indispensable trace element for *Lemna minor*. Experientia (Basel), Vol. 14, pp. 333–334.

Cobalt

1. BOLLE-JONES, E. W. and V. R. MALLIKARJUNESWARA
1957. A beneficial effect of cobalt on the growth of the rubber plant (*Hevea brasilienses*). Nature, Vol. 179, pp. 738–739.

2. BUDDHARI, W.
1960. Cobalt as an essential element for blue-green algae (Doctor's thesis). University of California, Berkeley, California.

3. HOLM-HANSEN, O., G. C. GERLOFF and F. SKOOG
1954. Cobalt as an essential element for blue-green algae. Physiol. Plantarum, Vol. 7, pp. 665–675.

4. REISENAUER, H. M.
1960. Cobalt in nitrogen fixation by a legume. Nature, Vol. 186, pp. 375–376.

5. SHAUKAT-AHMED and H. J. EVANS
1960. Cobalt: a micronutrient element for the growth of soybean plants under symbiotic conditions. Soil Sci., Vol. 90, pp. 205–210.

6. SHAUKAT-AHMED and H. J. EVANS
1961. The essentiality of cobalt for soybean plants grown under symbiotic conditions. Proc. Nat. Acad. Sci., Vol. 47, pp. 24–36.

7. YOUNG, R. S.
1956. Cobalt in biology and biochemistry. Science Progress, Vol. 44, pp. 16–37.

Copper

1. ARNON, D. I.
1950. Functional aspects of copper in plants. In: McElroy and Glass (eds.). A symposium on copper metabolism. pp. 89–114. The Johns Hopkins Press. Baltimore, Maryland.

2. LIPMAN, C. B. and G. MACKINNEY
1931. Proof of the essential nature of copper deficiency. Plant Physiol., Vol. 6, pp. 593–599.

3. SOMMER, A. L.
1931. Copper as an essential for plant growth. Plant Physiol., Vol. 6, pp. 339–345.

4. SOMMER, A. L.
1945. Copper and plant growth. Soil Sci., Vol. 60, pp. 71–79.

5. STEINBERG, R. A.
1950. The copper nutrition of green plants and fungi. pp. 115–140. In: McElory and Glass (eds.). A symposium on copper metabolism. The Johns Hopkins Press, Baltimore, Maryland.

Gallium

1. CULKIN, F. and J. P. RILEY
1958. The occurrence of gallium in marine organisms. J. Mar. Biol. Assoc., Vol. 37, pp. 607–615.

Iron

1. GINES, F. G.
1930. Relative effects of different iron salts upon growth and development of young rice plants. Philippine Agr., Vol. 19, pp. 43–52. Experiment Sta. Rec., Vol. 67, p. 23.

2. HOPKINS, E. F. and F. B. WANN
1927. Iron requirement for *Chlorella*. Bot. Gaz., Vol. 84, pp. 407–427.

Manganese

1. BROWN, T. E., H. C. EYSTER, and H. A. TANNER
1958. Physiological effects of manganese deficiency. Chapt. 10 pp. 135–155. In: Lamb, Bentley, and Beattie (eds.). Trace elements. Academic Press, Inc., New York.

2. EYSTER, C., et al.
1958. Manganese requirement with respect to growth, Hill reaction, and photosynthesis. Plant Physiol., Vol. 33, pp. 235–241.

3. HOPKINS, E. F.
1930. The necessity and function of manganese in the growth of *Chlorella sp.* Science, Vol. 72, pp. 609–610.

4. MCHARGUE, J. S.
1922. The role of manganese in plants. J. Am. Chem. Soc., Vol. 44, pp. 1592–1598.

5. PIRSON, A. and L. BERGMANN
1955. Manganese requirement and carbon source in *Chlorella*. Nature, Vol. 176, pp. 209–210.

Molybdenum

1. ANDERSON, A. J.
1956. Molybdenum deficiencies in legumes of Australia. Soil Sci., Vol. 81, pp. 173–182.

2. ARNON, D. I.
1955. Molybdenum in relation to nitrogen metabolism. I. Assimilation of nitrate nitrogen by *Scenedesmus*. Physiol. Plantarum, Vol. 8, pp. 538–551.

3. ARNON, D. I. and P. R. STOUT
1939. Molybdenum as an essential element for higher plants. Plant Physiol., Vol 14, pp. 599–602.

4. BUREMA, S. J. and K. T. WIERINGA
1942. Molybdenum as a growth factor for *Azotobacter chrococcum*. Antonie van Leeuwenhoek. J. Microbiol. Serol., Vol. 8, pp. 123–133.

5. EVANS, H. J.
1956. Role of molybdenum in plant nutrition. Soil Sci., Vol. 81, pp. 199–208.

6. HEWITT, E. J.
1956. Symptoms of molybdenum deficiency in plants. Soil Sci., Vol. 81, pp. 159–171.

7. HOAGLAND, D. R.
1945. Molybdenum in relation to plant growth. Soil Sci., Vol. 60, pp. 119–123.

8. ICHIOKA, P. S. and D. I. ARNON
1955. Molybdenum in relation to nitrogen metabolism. II. Assimilation of ammonia and urea without molybdenum by *Scenedesmus*. Physiol. Plantarum, Vol. 8, pp. 552–560.

9. MULDER, E. G.
1948. Importance of molybdenum in the nitrogen metabolism of microorganisms and higher plants. Plant and Soil, Vol. 1, pp. 94–119.

10. PIPER, C. S.

1940. Molybdenum as an essential for plant growth. J. Australian Inst. Agr. Sci., Vol. 6, pp. 162–164.

11. STEINBERG, R. A.

1936. Relation of accessory growth substances to heavy metals including molybdenum, in the nutrition of *Aspergillus niger*. J. Agr. Res., Vol. 52, pp. 438–448.

12. STOUT, P. R. and C. M. JOHNSON

1956. Molybdenum deficiency in horticultural and field crops. Soil Sci., Vol. 81, pp. 183–190.

Silicon

1. ISHIBASHI, H.

1937. The effect of silica on the growth of cultivated plants. V. The effect of silica on the growth of rice plants growing on soils of various depth. J. Sci. Soil and Manure (Japan), Vol. 11, pp. 535–549.

2. JORGENSEN, E. G.

1955. Variations in the silica content of diatoms. Physiol. Plantarum, Vol. 8, pp. 840–845.

3. JORGENSEN, E. G.

1955. Solubility of the silica in diatoms. Physiol. Plantarum, Vol. 8, pp. 846–851.

4. LEWIN, J. C.

1954. Silicon metabolism in diatoms. I. Evidence for the role of reduced sulfur compounds in silicon utilization. J. Gen. Physiol., Vol. 37, pp. 589–599.

5. LEWIN, J. C.

1957. Silicon metabolism in diatoms. IV. Growth and frustule formation in *Navicula pelliculosa*. Can. J. Microbiol., Vol. 3, pp. 427–433.

6. RALEIGH, G. J.

1939. Evidence for the essentiality of silicon for growth of the beet plant. Plant Physiol., Vol. 14, pp. 823–828.

7. SOMMER, A.

1926. Studies concerning essential nature of aluminum and silicon for plant growth. Univ. of Calif. Publ. Agr. Sci., Vol. 5, p. 2.

Sodium

1. BROWNELL, P. F. and S. G. WOOD

1957. Sodium as an essential micronutrient element for *Atriplex vesicaria* Heward. Nature, Vol. 179, pp. 635–636.

2. HODGSON, J. F.

1955. I. The essentiality of sodium for plant growth. II. Quantitative determination of sodium with the flame photometer (Doctoral dissertation). University of Wisconsin.

3. LEHR, J. J.

1941. The importance of sodium for plant nutrition. I. Soil Sci., Vol. 52, pp. 237–244.

4. LEHR, J. J.

1941. The importance of sodium for plant nutrition. II. Effect on beets of the secondary ions in nitrate fertilizers. Soil Sci., Vol. 52, pp. 373–379.

5. LEHR, J. J. and J. M. WYBENGA

1955. Exploratory pot experiments on sensitiveness of different crops to sodium. C. Flax. Plant and Soil, Vol. 6, pp. 251–261.

6. LEHR, J. J. and J. M. WYBENGA

1958. Exploratory pot experiments on sensitiveness of different crops to sodium. D. Barley. Plant and Soil, Vol. 9, pp. 237–253.

7. MATTHEW, E. D.

1941. Evidence of the value of the sodium ion in cotton fertilizers. Georgia Agr. Exp. Sta. Circ. 127.

8. WYBENGA, J. M. and J. J. LEHR

1958. Exploratory pot experiments on sensitiveness of different crops to sodium. E. Red table beet. Plant and Soil, Vol. 9, pp. 385–394.

Vanadium

1. ARNON, D. I. and G. WESSEL
   1953. Vanadium as an essential element for green plants. Nature, Vol. 172, pp. 1039–1040.

2. BERTRAND, D.
   1942. Vanadium, an oligosynergic element for *Aspergillus niger*. Ann. Inst. Past., Vol. 68, pp. 226–244.

3. WARBURG, O., G. KRIPPAHL, and W. BUCHHOLZ
   1955. Action of vanadium on the photosynthesis. Z. Naturforsch. Vol. 10b, p. 422.

Zinc

1. BROWN, L. C. and C. C. WILSON
   1952. Some effect of zinc on several species of *Gossypium sp.* L. Plant Physiol., Vol. 27, pp. 812–817.

2. CAMP, A. F.
   1945. Zinc as a nutrient in plant growth. Soil Sci., Vol. 60, pp. 157–164.

3. CHANDLER, W. H.
   1937. Zinc as a nutrient for plants. Bot. Gaz., Vol. 98, pp. 625–646.

4. FOSTER, J. N. and F. W. DENISON, JR.
   1940. Role of zinc in metabolism. Nature, Vol. 166, pp. 833–834.

5. HOCH, F. L. and B. L. VALLEE
   1958. The metabolic role of zinc. Chapt. 22. In Lamb, Bentley, and Beattie (eds.). Trace elements. Academic Press, Inc., New York.

6. MEDINA, A. and D. J. D. NICHOLAS
   1957. A zinc-dependent hexokinase from *Neurospora crassa*. Nature, Vol. 179, pp. 87–88.

7. MEDINA, A. and D. J. D. NICHOLAS
   1957. Some properties of a zinc-dependent hexokinase from *Neurospora crassa*. Biochem. J., Vol. 66, pp. 573–578.

8. NASON, A., N. O. KAPLAN and S. P. COLOWICK
1951. Changes in enzymatic constitution in zinc-deficient *Neurospora*. J. Biol. Chem., Vol. 188, pp. 397–406.

9. PRICE, C. A. and E. MILLAR
1962 Zinc, growth and respiration in *Euglena*. Plant Physsiol., Vol. 37, pp. 423–427.

10. PRICE, C. A. and B. L. VALLEE
1962. *Euglena gracilis*: A test organism for study of zinc. Plant Physiol., Vol. 37, pp. 428–433.

11. QUINLAN-WATSON, T. A. F.
1951. Aldolase activity in zinc deficient plants. Nature, Vol. 167, pp. 1033–1034.

12. QUINLAN-WATSON, T. A. F.
1953. The effect of zinc deficiency on the aldolase activity in the leaves of oats and clover. Biochem. J., Vol. 53, pp. 457–460.

13. REED, H. S.
1946. Effects of zinc deficiency on phosphate metabolism of the tomato plant. Am. J. Botany, Vol. 33, pp. 778–784.

14. SKOOG, F.
1940. Relationships between zinc and auxin in the growth of higher-plants. Am. J. Botany, Vol. 27, pp. 39–951.

15. TSUI, C.
1948. The role of zinc in auxin synthesis in the tomato plant. Am. J. Botany, Vol. 35, pp. 172–179.

16. VIETS, F. G., JR., L. C. BOAWN and C. L. CRAWFORD
1954. Zinc content of bean plants in relation to deficiency symptoms and yield. Plant Physiol., Vol. 29, pp. 76–79.

17. VIETS, F. G., JR., et al.
1953. Zinc deficiency in corn in Central Washington. Agron. J., Vol. 45, pp. 559–565.

1. BRENCHLEY, W. E.
1914. On the action of certain compounds of zinc, arsenic, and boron on the growth of plants. Ann. Botany, Vol. 28, pp. 283–301.

2. LILL, J. G., S. BYALL and L. A. HURST
1938. The effect of applications of common salt upon the yield and quality of sugar beets and upon the composition of the ash. J. Am. Soc. Agron., Vol. 30, pp. 97–106.

3. LIPMAN, C. B.
1938. Importance of silicon, aluminum and chlorine for higher plants. Soil Sci., Vol. 45, pp. 189–198.

4. MARSTON, H. R.
1952. Cobalt, copper and molybdenum in the nutrition of animals and plants. Physiol. Rev., Vol. 32, pp. 66–121.

5. MAZE, P.
1914. Influences respectives des elements mineral sur le development du mais. Ann. Inst. Pasteur, Vol. 28, pp. 1–48.

6. MAZE, P.
1936. The role of special elements (boron, copper, zinc, manganese, etc.) in plant nutrition. Ann. Rev. Biochem., Vol. 5, pp. 525–538.

7. MULLISON, W. R. and E. MULLISON
1942. Growth responses of barley seedlings in relation to potassium and sodium nutrition. Plant Physiol., Vol. 17, pp. 632–644.

8. NASON, A.
1958. The metabolic role of vanadium and molybdenum in plants and animals. Chapt. 19. In: Lamb, Bentley, and Beattie (eds.). Trace elements. Academic Press, Inc., New York.

9. NOACK, K. and A. PIRSON
1939. Effect of iron and manganese on nitrogen assimilation of *Chlorella*. Ber. Deut. botan. Ges., Vol. 57, pp. 442–452.

10. OZANNE, P. G., J. T. WOOLLEY, and T. C. BROYER
1957. Chlorine and bromine in the nutrition of higher plants. Australian J. Biol. Sci., Vol. 10, pp. 66–79.

11. SCOTT, G. T.
1943. The mineral composition of *Chlorella pyrenoidosa* grown in culture medium containing varying concentrations of calcium, magnesium, potassium and sodium. J. Cellular Comp. Physiol., Vol. 21, pp. 327–338.

12. SOMMER, A. L. and C. B. LIPMAN
1926. Evidence on the indispensable nature of zinc and boron for higher green plants. Plant Physiol., Vol. 1, pp. 231–249.

13. WALKER, J. B.
1953. Inorganic micronutrient requirements of *Chlorella*. I. Requirements for calcium (or strontium), copper, and molybdenum. Arch. Biochem. Biophys., Vol. 46, pp. 1–11.

14. WALKER, J. B.
1954. Inorganic micronutrient requirements of *Chlorella*. II. Quantitative requirements for iron, manganese, and zinc. Arch. Biochem. Biophys., Vol. 53, pp. 1–8.

15. WOOLLEY, J. T.
1957. Sodium and silicon as nutrients for the tomato plant. Plant Physiol., Vol. 32, pp. 317–321.

VIRUSES AND PARASITES

1. CANTER, H. M.
1950. Fungal parasites of the phytoplankton. I. Ann. Bot., Lond. n. s., Vol. 14, pp. 263–289.

2. CANTER, H. M.
1951. Fungal parasites of the phytoplankton. II. Ann. Bot., Lond. n. s., Vol. 15, pp. 129–156.

3. CANTER, H. M.
1954. Fungal parasites of the phytoplankton. III. Trans. Brit Mycol Soc, Vol. 37, pp. 111–132.

4. CANTER, H. M. and J. W. G. LUND
1948. Studies on plankton parasites. I. Fluctuations in the numbers of *Asterionella formosa* Hass. In relation to fungal epidemics New Phytol., Vol. 47, pp. 238–261.

5. CANTER, H. M. and J. W. G. LUND
1951. Studies on plankton parasites. III. Examples of the interaction between parasitism and other factors determining the growth of diatoms. Ann. Bot., Lond. n. s., Vol. 15, pp. 359–371.

6. CANTER, H. M. and J. W. G. LUND
1953. Studies on plankton parasites. II. The parasitism of diatoms with special reference to lakes in the English Lake district. Trans. Brit. Mycol. Soc., Vol. 36, pp. 13–37.

7. SAFFERMAN, R. S. and M. E. MORRIS
1962. Evaluation of natural products for algicidal properties. Applied Microbiology, Vol. 10, pp. 289–292.

8. SAFFERMAN, R. S. and M. E. MORRIS
1963. Algal Virus: Isolation. Science, Vol. 140, pp. 679–680.

9. SAFFERMAN, R. S. and M. E. MORRIS
1964. Control of algae with viruses. J. Am. Water Works Assoc., Vol. 56, pp. 1217–1224.

10. SAFFERMAN, R. S. and M. E. MORRIS
1964. Growth characteristics of the blue-green algal virus LPP–1. Journ. of Bacteriology, Vol. 88, pp. 771–775.

11. SCHNEIDER, I. R., T. O. DIEVER, and R. S. SAFFERMAN
1964. Blue-green algal virus LPP–1: purification and partial characterization. Science, Vol. 144, pp. 1127–1130.

VITAMINS

ASSAY METHODS

1. ADAIR, E. J. and H. S. VISHNIAC
1958. Marine fungus requiring vitamin B_{12}. Science, Vol. 127, pp. 147–148.

2. BURKHOLDER, P. R.
1951. Determination of vitamin B_{12} with a mutant strain of *Escherichia coli*. Science, Vol. 114, pp. 459–460.

3. BURKHOLDER, P. R. and L. M. BURKHOLDER
1956. Microbiological assay of vitamin B_{12} in marine solids. Science, Vol. 123, pp. 1071–1073.

4. COATES, M. E. and J. E. FORD
1955. Methods of measurement of vitamin B_{12}. In: R. T. Williams, "The Biochemistry of Vitamin B_{12}." Biochem. Soc. Symposia, Vol. 13, pp. 36–51.

5. DAISLEY, K. W.
1958. A method for the measurement of vitamin B_{12} concentration in sea water. J. Mar. Biol. Assoc., Vol. 37, pp. 673–681.

6. DROOP, M. R.
1955. A suggested method for the assay of vitamin B_{12} in sea water. J. Mar. Biol. Assoc., Vol. 34, pp. 435–440.

7. FORD, J. E.
1952. The microbiological assay of vitamin B_{12}. Brit. J. Nutrit., Vol. 6, pp. 324–330.

8. FORD, J. E.
1953. The microbiological assay of "Vitamin B_{12}." The specificity of the requirement of *Ochromonas malhamensis* for cyanocobalamin. Brit. J. Nutrit., Vol. 7, pp. 299–306.

9. GOLD, K.
1964. A microbiological assay for vitamin B_{12} in seawater using radiocarbon. Limnol. and Oceanog., Vol. 9, pp. 343–347.

10. GOLD, K.
1964. Aspects of marine dinoflagellate nutrition measured by C^{14} assimilation J. Protozool., Vol. 11, pp. 85–89.

11. GREGORY, M. E.
1954. The microbiological assay of vitamin B_{12} in the milk of different animal species. Brit. J. Nutrit., Vol. 8, pp. 340–347.

12. HOFF-JORGENSEN, E.
1954. Microbiological assay of vitamin B_{12}. In: B. Glick "Methods of Biochemical Analysis." Vol. 1, Interscience, New York, pp. 81–113.

13. HUTNER, S. H., M. K. BACH, and G. L. M. ROSS
1956. A sugar-containing basal medium for vitamin B_{12}-assay with *Euglena*; application to body fluids. J. Protozool., Vol. 3, pp. 101–112.

14. HUTNER, S. H., A. CURY, and H. BAKER
1958. Microbiological assays. Anal. Chem., Vol. 30, pp. 849–867.

15. KASHIWADA, K., D. KAKIMOTO, T. MORITA, A. KANAZAQA, and K. KAWAGOE
1957. Studies on vitamin B_{12} in sea water. II. On the assay method and the distribution of the vitamin B_{12} to the ocean. Bull. Jap. Soc. Sci. Fisheries, Vol. 22, pp. 637–640.

16. LEVIN, G. V.
1963. Rapid microbiological determinations with radioisotopes, pp. 95–133. In: W. W. Umbreit, (ed), Advances in Applied Microbiology, Vol. 5, Academic Press, New York.

17. OSTERGAARD KRISTENSEN, H. P.
1954. Investigations into the *Euglena gracilis* method for quantitative assay of vitamin B_{12}. Acta Physiol., Scand., Vol. 33, pp. 232–237.

18. PROVASOLI, L. and K. GOLD
1959. *Gyrodinium cohnii*, an assay organism for biotin and thiamine. Int. Oceanogr. Cong. Preprints, pp. 931–933.

19. PROVASOLI, L. and I. J. PINTNER
1953. Assay of vitamin B_{12} in sea water. Proc. Soc. Protozool., Vol. 4, p. 10.

20. RYTHER, J. H. and R. R. L. GUILLARD
1962. Studies of marine planktonic diatoms. II. Use of *Cyclotella nana* for assay of vitamin B_{12} in seawater. Can. J. Microbiol., Vol. 8, pp. 437–446.

21. TOMIYAMA, T.
1959. Preliminary report on the determination and distribution of vitamin B_{12} in the sea. Preprints Inter. Oceanog. Cong., pp. 941–942.

22. VISHNIAC, H. S.
1961. A biological assay for Thiamine in seawater. Limnol. Oceanog., Vol. 6, pp. 31–35.

1. AKAO, A., et al.
1957. Vitamin C in Asakusa sea-weed. Nihon Univ. Med. J., Vol. 16, pp. 1103–1107. Phycol. Soc. Am., News Bull., Vol. 12, p. 1 (April 1959).

2. BENOIT, R. J.
1957. Preliminary observations on cobalt and vitamin B_{12} in freshwater. Limnol. and Oceanog., Vol. 2, pp. 233–240.

3. BURKHOLDER, P R. and L. M. BURKHOLDER
1956. Vitamin B_{12} in suspended solids and marsh muds collected along the coast of Georgia. Limnol. and Oceanog., Vol. 1, pp. 202–208.

4. BURKHOLDER, P. R.
1958. Studies on B vitamins in relation to productivity of the Bahia Fosforescente, Pureto Rico. Bull. Mar. Sci. of the Gulf and Carribbean, Vol. 8, pp. 201–223.

5. COOK, B. B.
1962. The nutritive value of waste-grown algae. American Journal of Public Health, Vol. 52, pp. 243–251.

6. COWEY, C. B.
1956. A preliminary investigation of the variation of vitamins B_{12} in oceanic and coastal waters. J. Mar. Biol. Assoc., Vol. 35, pp. 609–620.

7. DAISLEY, K. W.
1959. Vitamin B_{12} in sea water. Preprints Inter. Oceanog. Cong., pp. 914–915.

8. DAISLEY, K. W. and L. R. FISHER
1958. Vertical distribution of vitamin B_{12} in the sea. J. Mar. Biol. Assoc. Vol. 37, pp. 683–686.

9. ERICSON, L. E. and L. LEWIS
1953. On the occurrence of vitamin B_{12}-factors in marine algae. Ark. Kemi., Vol. 6, pp. 427–442.

10. HOOVER, S. R., L. YASEWEIEZ, J. B. PEPINSKY, and N. PORGES
1951. Vitamin B_{12} in activated sewage sludge. Science, Vol. 114, p. 213.

11. HUTCHINSON, G. E.

1943. Thiamine in lake waters and aquatic organisms. Arch. Biochem., Vol. 2, pp. 143–150.

12. HUTCHINSON, G. E. and J. K. SETLOW

1946. Limnological studies in Connecticut. VIII. The niacin cycle in a small inland lake. Ecol., Vol. 27, pp. 13–22.

13. KASHIWADA, K., D. KAKIMOTO, and K. KAWAGOE

1957. Studies on vitamin B_{12} in sea water. III. On the diurnal fluctuation of vitamin B_{12} in the sea and vertical distribution in the lake. Bull. Jap. Soc. Sci. Fisheries, Vol. 23, pp. 420–453.

14. MENZEL, D. W. and J. P. SPAETH

1962. Occurrence of vitamin B_{12} in the Sargasso Sea. Limnol. and Oceanog., Vol. 7, pp. 151–154.

15. PROVASOLI, L.

1961. Micronutrients and heterotrophy as possible factors in bloom production in natural waters. Algae and Metropolitan Wastes, U.S. Public Health Service, SEC TR W61–3, pp. 48–56.

16. PROVASOLI, L.

1963. Organic regulation of phytoplankton fertility. In: The Sea, Vol. 2, The Composition of Sea-Water Comparative and Descriptive Oceanography, M. N. Hill, General Editor, Interscience Publishers, N. Y., pp. 165–219.

17. SATHYANARAYANA, R., C. A. JASTRY, H. N. BHAGAVAN, and B. R. BALIJA

1959. Vitamin B_{12} in sewage sludges. Science, Vol. 129, p. 276.

18. SOUTHCOTT, B. A. and H. L. A. TARR

1953. Vitamin B_{12} in marine invertebrates and seaweeds. Prog. Rep. Pacific Coast Sta.; Fish. Res. Bd. Canada, No. 95, pp. 45–47.

19. STARR, T. J.

1956. Relative amounts of vitamin B_{12} in detritus from oceanic and estuarine environments near Sapelo Island, Georgia Ecol., Vol. 37, pp. 658–664.

20. TEERI, A. E. and R. E. BIEBER
1958. B-complex vitamins in certain brown and red algae. Science, Vol. 127, p. 1500. Chem. Abs., Vol. 52, 16514b, 1958.

21. VISHNIAC, H. S. and G. RILEY
1959. B_{12} and thiamine in Long Island Sound: patterns of distribution and ecological significance. Inter. Oceanog. Congress, Preprints, pp. 942–943.

22. VISHNIAC, H. S. and G. A. RILEY
1961. Cobalamin and thiamine in Long Island Sound: patterns of distribution and ecological significance. Limnol. and Oceanog., Vol. 6, pp. 36–41.

Organism Requirements

1. ADAIR, E. J. and H. S. VISHNIAC
1958. Marine fungus requiring vitamin B_{12}. Science, Vol. 127, pp. 147–148.

2. COOKE, W. B.
1957. Nutritional requirements of nine common sewage fungi. Sewage and Industrial Wastes, Vol. 29, pp. 1243–1251.

3. DAISLEY, K. W.
1957. Vitamin B_{12} in marine ecology. Nature, Vol. 180, pp. 1042–1043.

4. DROOP, M. R.
1954. Cobalamin requirement in Chrysophyceae. Nature, Lond., Vol. 174, p. 520.

5. DROOP, M. R.
1955. A pelagic marine diatom requiring cobalamin. J. Mar. Biol. Assoc., Vol. 34, pp. 229–231.

6. DROOP, M. R.
1957. Vitamin B_{12} in marine ecology. Nature, Vol. 180, pp. 1041–1042.

7. DROOP, M. R.
1958. Requirement for thiamine among some marine and supralittoral Protista. J. Mar. Biol. Assoc., Vol. 37, pp. 323–329.

8. DROOP, M. R.
1959. Water-soluble factors in the nutrition of *Oxyrrhis marina*. J. Mar. Biol. Assoc., Vol. 38, pp. 605–620.

9. DROOP, M. R.
1961. Vitamin B_{12} and marine ecology: The response of *Monochrysis lutheri*. J. Mar. Biol. Assoc., Vol. 41, pp. 69–76.

10. DROOP, M. R., J. J. A. MCLAUGHLIN, I. J. PINTNER and L. PROVASOLI
1959. Specificity of some protophytes toward vitamin B_{12} like compounds. Preprints Inter. Oceanog. Cong., pp. 916–918.

11. ERICSON, L. E.
1952. Uptake of radioactive cobalt and vitamin B_{12} by some marine algae. Chem. and Ind. London, Vol. 34, pp. 829–830.

12. FORD, J. E.
1958. B_{12}-vitamins and growth of the flagellate *Ochromonas malhamensis*. J. Gen. Microbiol., Vol. 19, pp. 161–172.

13. FORD, J. E., M. E. GREGORY, and E. S. HOLDSWORTH
1955. Uptake of B_{12}-vitamins in *Ochromonas malhamensis*. Biochem. J., Vol. 61, p. 23.

14. FORD, J. E. and S. H. HUNTER
1955. Role of vitamin B_{12} in the metabolism of microorganisms. Vitam. and Horm., Vol. 13, pp. 101–136.

15. FRIES, L.
1959. *Goniotrichum elegans*: a marine red alga requiring vitamin B_{12}. Nature, Vol. 183, pp. 558–559.

16. GUILLARD, R. R. L. and V. CASSIE
1963. Minimum Cyanocobalamin requirements of some marine centric diatoms. Limnol. and Oceanog., Vol. 8, pp. 161–165.

17. HUTNER, S. H. and L. PROVASOLI
1953. A pigmented marine diatom requiring vitamin B_{12} and uracil. News Bull. Phycol. Soc. Amer., Vol. 6, pp. 7–8.

18. LEWIN, J. C. and R. A. LEWIN
1959. Auxotrophy and heterotrophy in marine littoral diatoms. Preprints Inter. Oceanog. Cong., pp. 928–929.

19. LEWIN, R. A.
1954. A marine *Stichococcus sp.* which requires vitamin B_{12}. J. Gen. Microbiol., Vol. 10, pp. 93–96.

20. LOCHHEAD, A. G. and R. H. THEXTON
1951. Vitamin B_{12} as a growth factor for soil bacteria. Nature, Vol. 167, p. 1034.

21. MCLAUGHLIN, J. J. A. and P. A. ZAHL
1959. Vitamin requirements in symbiotic algae. Inter. Oceanog. Congress, Preprints, pp. 903–931.

22. PROVASOLI, L.
1958. Nutrition and ecology of protozoa and algae. Ann. Rev. Microbiol., Vol. 12, pp. 279–308.

23. PROVASOLI, L.
1961. Micronutrients and heterotrophy as possible factors in bloom production in natural waters. Algae and Metropolitan Wastes, U.S. Public Health Service, SEC TR W61–3, pp. 48–56.

24. PROVASOLI, L.
1964. Effect of external metabolites on algae. Int. Vereinigung Fur Theor. und Angewandte Limnologie, Stuttgart, p. 804.

25. PROVASOLI, L. and I. J. PINTNER
1953. Ecological implications of in vitro nutritional requirements of algal flagellates. Ann. N. Y. Acad. Sci., Vol. 56, pp. 839–851.

26. SWEENEY, B. M.
1954. *Gymnodinium splendens*, a marine dinoflagellate requiring vitamin B_{12}. Amer. J. Bot., Vol. 41, pp. 821–824.

27. VAN BAALEN, C.
1961. Vitamin B_{12} requirement of a marine blue-green alga. Science, Vol. 133, pp. 1922–1923.

Synthesized

1. BROWN, F., W. F. J. CUTHBERTSON and G. E. FOGG
1955. Vitamin B_{12} activity of *Chlorella vulgaris*, Beij. and *Anabaena cylindrica* Lemm. Nature, Vol. 177, p. 188.

2. BURKHOLDER, P. R.
1959. Vitamin-producing bacteria in the sea. Inter. Oceanog. Congress. Preprints, pp. 912–913.

3. BURTON, M. O. and A. G. LOCKHEAD
1951. Studies on the production of vitamin B_{12} active substances by microorganisms. Canad. J. Bot., Vol. 29, pp. 352–359.

4. COMBS, C. F.
1952. Algae (*Chlorella*) as a source of nutrients for the chick. Science, Vol. 116, pp. 453–454.

5. DARKEN, M. A.
1953. Production of vitamin B_{12} by microorganisms and its occurrence in plant tissues. Botan. Review, Vol. 19, pp. 99–130.

6. ERICSON, L. E. and L. LEWIS
1953. On the occurrence of vitamin B_{12}-factors in marine algae. Ark. f. Kemi., Vol. 6, pp. 427–442.

7. HASHIMOTO, Y.
1954. Vitamin B_{12} in marine and freshwater algae. J. Vitaminol., Vol. 1, pp. 49–54.

8. ROBBINS, W. J., A. HERVEY, and M. E. STEBBINS
1950. Studies on *Euglena* and vitamin B_{12}. Bull. Torrey Bot. Club. Vol. 77, pp. 423–441.

9. ROBBINS, W. J., A. HERVEY, and M. E. STEBBINS
1951. Further observation on *Euglena* and B_{12}. Bull. Torrey Bot. Club. Vol. 78, pp. 363–375.

10. ROBBINS, W. J. and V. KAVANAGH
1942. Vitamin deficiencies of the filamentous fungi. Bot. Rev., Vol. 8, p. 411.

11. STARR, T. J., M. E. JONES, and D. MARTINEZ
1957. The production of vitamin B_{12}-active substances by marine bacteria. Limnol. and Oceanog. Vol. 2, pp. 114–119.

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